Claims

[c1] A sputtering source comprising:
a cathode assembly that is positioned adjacent to an anode, the cathode assembly including a sputtering target;
an ionization source that generates a weakly-ionized plasma proximate to the anode and the cathode assembly; and
a power supply that produces an electric field between the anode and the cathode assembly, the electric field creating a strongly-ionized plasma from the weakly-ionized plasma, the strongly-ionized plasma comprising a first plurality of ions that impact the sputtering target thereby generating sufficient thermal energy in the sputtering target to cause a sputtering yield of the sputtering target to be non-linearly related to a temperature of the sputtering target.

[c2] The sputtering source of claim 1 wherein the electric field comprises a quasi-static electric field.

[c3] The sputtering source of claim 1 wherein the electric field comprises an electrical pulse.

[c4] The sputtering source of claim 3 further comprising a gas exchange means for exchanging the strongly-ionized plasma with a new volume of feed gas while applying the electrical pulse across the new volume of feed gas to generate additional strongly-ionized plasma comprising a second plurality of ions, the second plurality of ions impacting the sputtering target, thereby generating additional thermal energy in the sputter target.

[c5] The sputtering source of claim 3 further comprising a gas exchange means for exchanging the weakly-ionized plasma with a new volume of feed gas while applying the electrical pulse across the new volume of feed gas.

[c6] The sputtering source of claim 1 wherein the thermal energy generated by the first plurality of ions that impact the sputtering target does not substantially increase an average temperature of the sputtering target.

[c7] The sputtering source of claim 1 further comprising a magnet that is positioned to generate a magnetic field proximate to the weakly-ionized plasma, the

magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target.

[c8] The sputtering source of claim 1 wherein the electrical field across the weakly-ionized plasma excites atoms in the weakly-ionized plasma and generates secondary electrons from the cathode assembly, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.

[c9] The sputtering source of claim 1 wherein the power supply generates a constant power.

[c10] The sputtering source of claim 1 wherein the power supply generates a constant voltage.

[c11] The sputtering source of claim 1 wherein the ionization source is chosen from the group comprising an electrode coupled to a DC power supply, an electrode coupled to an AC power supply, a UV source, an X-ray source, an electron beam source, an ion beam source, an inductively coupled plasma source, a capacitively coupled plasma source, and a microwave plasma source.

[c12] The sputtering source of claim 1 wherein a rise time of the electric field is chosen to increase an ionization rate of the strongly-ionized plasma.

[c13] The sputtering source of claim 1 wherein the weakly-ionized plasma reduces the probability of developing an electrical breakdown condition between the anode and the cathode assembly.

[c14] The sputtering source of claim 1 wherein the strongly-ionized plasma is substantially uniform proximate to the cathode assembly.

[c15] The sputtering source of claim 1 wherein a distance between the anode and the cathode assembly is chosen to increase an ionization rate of strongly-ionized plasma.

[c16] A method for high deposition rate sputtering, the method comprising:
ionizing a feed gas to generate a weakly-ionized plasma;
generating a strongly-ionized plasma from the weakly-ionized plasma, the

strongly-ionized plasma comprising a plurality of ions positioned proximate to a sputtering target; and

impacting the sputtering target with the plurality of ions to generate sufficient thermal energy in the sputtering target to cause a sputtering yield of the sputtering target to be non-linearly related to a temperature of the sputtering target.

[c17] The method of claim 16 further comprising generating a magnetic field proximate to the sputtering target, the magnetic field trapping electrons proximate to the sputtering target.

[c18] The method of claim 16 wherein the generating a strongly-ionized plasma comprises applying an electric field across the weakly-ionized plasma.

[c19] The method of claim 18 wherein the electric field generates excited atoms in the weakly-ionized plasma and generates secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.

[c20] The method of claim 16 further comprising exchanging a volume of the weakly-ionized plasma with a volume of the feed gas while ionizing the volume of the feed gas to create an additional volume of the weakly-ionized plasma.

[c21] The method of claim 16 further comprising exchanging a volume of the strongly-ionized plasma with a volume of the feed gas while generating an additional volume of the strongly-ionized plasma from the volume of the feed gas.

[c22] The method of claim 16 wherein the peak plasma density of the weakly-ionized plasma is less than about 10^{12} cm^{-3}.

[c23] The method of claim 16 wherein the weakly-ionized plasma reduces the probability of developing an electrical breakdown condition.

[c24] The method of claim 16 wherein the ionizing the feed gas comprises exposing the feed gas to one of a static electric field, an AC electric field, a quasi-static electric field, a pulsed electric field, UV radiation, X-ray radiation, an electron

beam, and an ion beam.

[c25] The method of claim 16 wherein the impacting the sputtering target with the plurality of ions causes a surface layer of the sputtering target to evaporate.

[c26] The method of claim 16 wherein the peak plasma density of the strongly-ionized plasma is greater than about 10^{12} cm^{-3}.

[c27] A sputtering source comprising:
a cathode assembly that is positioned adjacent to an anode, the cathode assembly including a sputtering target;
an ionization source that generates a weakly-ionized plasma from a first volume of feed gas that is located proximate to the cathode assembly;
a power supply that produces an electric field between the anode and the cathode assembly that creates a strongly-ionized plasma from the weakly-ionized plasma, the strongly-ionized plasma comprising a first plurality of ions; and
a gas controller for exchanging the strongly-ionized plasma with a second volume of feed gas while the electric field generates an additional strongly-ionized plasma comprising a second plurality of ions from the second volume of feed gas, the first and the second plurality of ions impacting the sputtering target to generate sufficient thermal energy in the sputtering target to cause a sputtering yield of the sputtering target to be non-linearly related to a temperature of the sputtering target.

[c28] The sputtering source of claim 27 further comprising a gas exchange means for exchanging the weakly-ionized plasma with a third volume of feed gas while applying the electrical pulse across the third volume of feed gas.

[c29] The sputtering source of claim 27 wherein the thermal energy generated by the first and the second plurality of ions that impact the sputtering target does not substantially increase an average temperature of the sputtering target.

[c30] A sputtering source comprising:
means for ionizing a feed gas to generate a weakly-ionized plasma;
means for generating a strongly-ionized plasma from the weakly-ionized

plasma, the strongly-ionized plasma comprising a plurality of ions proximate to a sputtering target; and

means for impacting the sputtering target with the plurality of ions to generate sufficient thermal energy in the sputtering target to cause a sputtering yield of the sputtering target to be non-linearly related to a temperature of the sputtering target.